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EXTENDED ABSTRACT

Zoning Map of Drought Characteristics under Climate Change Scenario using Copula Method in the Zayandeh Roud River Catchment

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Introduction

Drought is one of the extreme events that can impact vast areas gradually over time. Also understanding the implications of climate change on drought is important for water resources management in order to manage the available water resources in the basin appropriately. Having better understanding of drought condition, drought indices were developed. Several drought indices are used for identifying and quantifying droughts that among them the standardized precipitation index (SPI) provides proper results. Based on each drought indices, drought characteristics can be calculated namely drought duration and drought severity. Drought characteristics are highly correlated to each other. Trusting on one of the drought characteristics for managing the water resources may lead to inappropriate understanding of drought condition. Therefore, it is important to notice all characteristics together by using a joint distribution function that among them copula function is prevalently used in hydrology studies. Several studies were examined the impact of climate change on the drought conditions by using different drought indices in many basins in the word and Iran (Bazrafshan et al., 2015, Kouchaki ei al. 2007, Mahsafar, 2011, Eghtedarnejad et al., 2016, Naserzadeh and Ahmadi, 2012, Hoffman et al., 2009, Kirono et al., 2011, Selvaraju and. Baas, 2007, Lee et al., 2013, Serinaldi et al., 2009, Mirabbasi et al., 2013). There have been many studies which using copula function in order to compute the return period of the drought (Abbasian et al., 2014, Golian, 2010, Serinaldi et al., 2009, Mirabbasi et al., 2016, Maddadgar and Moradkhani, 2011, Chen et al., 2011).

Therefore, in this study drought condition was analyzed by using copula under climate change condition to have a better understanding of future drought situation and the return periods of drought events in the future. The SPI was used to extract the drought duration and drought severity in the ZayandehRoud River basin for a historical period (1979-2008), and the far future (2058-2099) by using 15 GCM models from the IPCC Fifth Assessment Report (AR5) scenarios. A significant past

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drought event in the basin was used as a benchmark with severity of -4.39 and duration of 6 months. The Archimedean and Elliptical families of copula functions were used to construct the joint distribution functions for evaluating the drought return periods in the basin. Results from historical analysis show that the return period of significant past drought is about 5 years and this period will increase to about 25 years in the future.

Methodology

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index was developed by McKee (1993). Since precipitation is the only data that is needed to calculate the SPI, the computation is relatively simple. Some studies used SPI to calculate the drought characteristics (Golian et al. 2015; Madadgar and Moradkhani 2011). Drought severity and duration were calculated based on computed SPI values by using the past available data of 30 years (1979-2008) in the ZayandehRoud basin. Drought duration is defined as successive months with SPI value less than -1 and drought severity as the accumulative SPI value during the period with successive SPI value less than -1. Lognormal, exponential, gamma and Weibull functions were selected as the candidate distribution function for drought duration and drought severity. Best-fitted distribution functions were selected based on the Bayesian Information Criterion (BIC) method for severity and duration.

Copula and Climate Change

Since there is a high correlation between drought characteristics, it is essential to use a joint distribution function. Copula is the joint distribution function which keeps all the information related to each dependence structure of marginal distribution. Copula functions are categorized into different families. Normal copula and t copula in elliptical copula family and Gumbel, Frank, and Clayton copula in the Archimedean copula family are commonly used copula functions families in the hydrology studies and are used in this study as well. The BIC method was used in order to choose the best fitted bivariate copula function in this study. The best-fitted copulas were used for the historical and future assessment of drought condition in order to calculate the return period of significant drought in the basin.

The last report of IPCC was AR5 which was published based on new set of scenarios, called Representative Concentration Pathways (RCPs), which describes an emission trajectory and concentration by the year 2100, and consequent forcing (Wayne 2013). For this study, daily precipitation data for the future periods of 84 years between 2016 and 2099 from 15 different GCMs for 2 different scenarios: RCP4.5 and RCP 8.5 was downloaded from the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset. These scenarios are representative of stabilized total radiated forcing and high greenhouse gas concentration levels, respectively. Return periods of significant drought were computed for 15 GCM models under selected scenarios.

Results and Discussion

İn this study, the 90 percentile of the drought duration and severity of past drought events in the historical period (1979-2008) was selected as the significant event. The characteristics of this significant historical drought were severity of SPI value of -4.39 and duration of 6 months. Then return period values of this event were calculated for the historical period (1979-2008), and far future (2058-2099) using bivariate copula for 15 GCM models under two selected senarios (RCP4.5 and RCP8.5). Finally spatial maps were generated by using the inverse distance weighting (IDW) method in the GIS software. For instance, Figure 1 shows the return period of severe drought based on the results of bivariate copula in the historical period (1979-2008).

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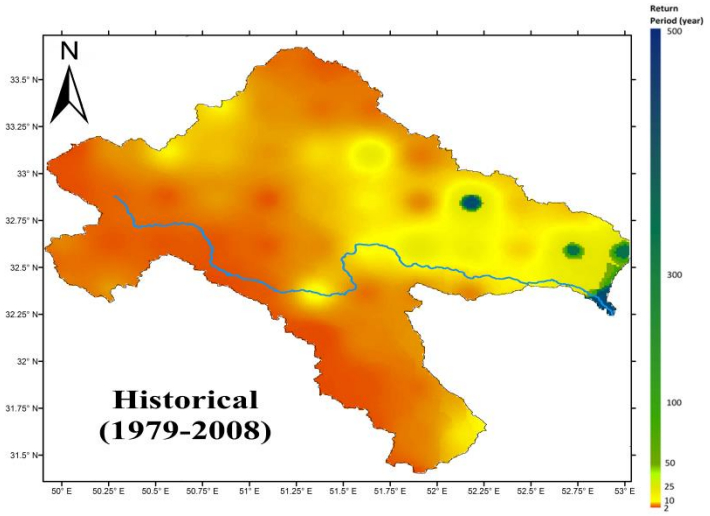

Fig. 1- Return period of severe drought (severity equal to SPI value of -4.39 and duration equal to 6 months) based on results of bivariate copula of Severity-Duration- in the historical period (1979-2008)

Conclusions

Drought is one of the extreme hydrological events that impact on agriculture and water resources. Climate change impact on drought may intensify the drought condition and its effects. So that, it is important to analyze the drought condition under climate change condition. In this study SPI index of drought was used to calculate the drought duration and drought severity in the ZayandehRoud basin in Iran. One of the severe past drought events during 1979 to 2008 was selected as the benchmark. Because of the high correlation between drought duration and severity the copula function was used as the joint distribution function to calculate the return period of significant drought in the past period (1979-2008), and the far future (2058-2099) for 15 GCM models under RCP4.5 and RCP8.5. Based on the results of 15 GCM models there is not any special trend for precipitation in the basin, but most of the models shows the trivial decreasing trend for precipitation especially in the upper part of the basin. Return periods of significant drought in the past is about less than 10 years and it may be less than 25 years in the near and future in the basin. However there is the uncertainty in the GCM models, it is essential to manage the water resources in the basin in order to overcome the possible severe drought condition in the future.

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